Diet of juvenile *Pagrus pagrus* (Sparidae) from sandy bottoms of the southern Tyrrhenian Sea

by

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ABSTRACT. - Feeding habits of juvenile red porgy *Pagrus pagrus* collected from a sandy bottom off Capo d'Orlando (southern Tyrrhenian Sea) were studied from 1994 to 1996. A total of 134 specimens were caught by boat seine and their guts preserved. Food items were identified, counted and weighted. Frequency of occurrence (%F), abundance (%N) and weight (%W) were used to calculate the index of relative importance (IRI) for each prey category. The analysis of prey items led to the identification of 78 mostly epibenthic taxa with crustaceans emerging as the dominant group, followed by molluscs and teleosts. Prey were neither partitioned by weight nor by abundance in the size range of fish examined, as confirmed by NPMANOVA performed on three fish size classes. Despite the large number of taxa found, few species accounted for most of the diet, suggesting specialized feeding, as confirmed by the low value of the Levins' standardized index. Individual feeding specialization on hermit crabs, brachyuran crabs and prosobranch gastropods was evidenced by a PCA performed on proportions of prey abundance.

RÉSUMÉ. - Régime alimentaire des juvéniles de *Pagrus pagrus* (Sparidae) de fonds meubles de la mer Tyrrhénienne méridionale.

Le régime alimentaire des pagres juvéniles (*Pagrus pagrus*) capturés sur un fond sableux du littoral de Capo d'Orlando (Tyrrhénienne méridionale) a été étudié de 1994 à 1996. Au total 134 individus ont été pêchés à la senne. Les proies ont été identifiées, comptées et pesées. L'indice de fréquence, les pourcentages en nombre et en poids ont été utilisés pour calculer l'indice d'importance relative (IRI) pour chaque item. Au total, 78 proies ont été identifiées. La plupart étaient épibenthiques et représentées principalement par les crustacés, suivis par les mollusques et les poissons téléostéens. Les proies ne sont pas réparties différemment, ni en nombre, ni en poids, dans l'intervalle de taille des individus examinés, ce qui est confirmé par une NPMANOVA calculée sur trois classes de taille de juvéniles. Malgré les nombreux items trouvés, la faible valeur de l'indice standardisé de Levins indique une alimentation spécialisée des pagres juvéniles. L'ACP, calculée sur la proportion relative de l'abondance des proies, a montré une spécialisation des individus vers les pagures, les brachyures et les gastéropodes prosobranches.

Key words. - Sparidae - *Pagrus pagrus* - MED - Tyrrhenian Sea - Diet - Ecology - Feeding habits.

The red porgy, *Pagrus pagrus* (Linnaeus, 1758) is common in the Mediterranean Sea and Atlantic Ocean, occurring in temperate and subtropical waters (Manooch and Hassler, 1978). Due to its importance as commercial fish, its biology has been well investigated in the Atlantic (Manooch and Huntsman, 1977; Hood and Johnson, 2000) as well as in the Mediterranean (Vassilopoulou, 1988; Vassilopoulou and Papaconstantinou, 1992). The red porgy is a coastal fish living on shallow sandy bottoms in its early life stages. As it matures, it migrates to deeper waters in rocky and detritic coralligenous bottoms (Arena and Bombace, 1970; Labropoulou *et al*., 1999). Its feeding habits change during the life span, shifting from soft bottom invertebrates and small fishes (Labropoulou *et al*., 1999) to a more diversified diet that includes hard-bottom species and planktonic prey (Manooch, 1977; Chakroun-Marzouk and Kartas, 1987). The red porgy is depicted as an opportunistic feeder, depending on feeding availability rather than preference or selection (Manooch, 1977; Papaconstantinou and Caragitsou, 1989). Although the feeding ecology of adults is well known, there has been little investigation on the diet of juveniles. In the eastern Mediterranean Sea, they feed mainly on decapods while fish represent a very small fraction of their diet; furthermore, they experience no seasonal variation in diet composition, but high variation with fish size (Labropoulou *et al*., 1999). Similar results, except slight seasonal variation in diet composition, were also found in the western Atlantic (Manooch, 1977) as well as in Tunisian waters (Chakroun-Marzouk and Kartas, 1987).

The knowledge of diet and feeding habits of juvenile red porgy, which represents a relevant component of the inshore communities, helps to understand mechanisms involved in

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resource partitioning and habitat use in coastal areas. Moreover, the recent use of red porgy as a high price cultured species increases the interest in its feeding biology, particularly during its juvenile stages.

In this paper, we describe the diet of juvenile red porgy living in an area of the southern Tyrrhenian Sea, exploited by an artisanal set-gear fishery, and the variation in diet composition with fish size.

MATERIAL AND METHODS

Study site and data collection

The study area is located off Capo d'Orlando, along the northern Sicilian coast (Fig. 1). The bottom is characterised by fine well-sorted sands, delimited by gravel and very coarse sand near the coast and by mud between 35 and 50 m depth offshore. Seagrass *Cymodocea nodosa* (Ucria) Aschers occurs at 10 to 20 m depth (Andaloro, 1994). Fish were caught during daytime between 5 and 25 m, in the summer-autumn period from 1994 to 1996 by seining. 38 specimens were caught in 1994, 91 in 1995, and 5 in 1996. Each fish was measured to the nearest mm [standard length (SL)] and weighed to the nearest 0.1 g. Guts were preserved in a 7% seawater solution of neutral formalin. Prey items from the stomachs were identified to the lowest possible taxon, counted and then weighed to the nearest 0.1 mg after removing excess water with blotting paper. Fish scales were considered as prey category only when they were found without any other part attributable to fish in the whole gut.

Data analysis

The cumulative number of prey categories was plotted against the cumulative number of randomly pooled stomachs analysed, in order to measure sample size sufficiency (Ferry and Cailliet, 1996). In case of non adequacy of the sample size, this analysis was repeated using grouped categories following ecological criteria. The sample size was considered sufficient when the cumulative prey-type curve fitted better a logistic curve than a linear relation (see details in Castriota *et al*., 2005). Contributions of different prey categories were assessed by calculating % frequency of occurrence (%F), % abundance (%N) and % weight (%W). These indices were then used to calculate the index of relative importance (IRI) for each taxonomic category using mass instead of volume (Hyslop, 1980; Hacunda, 1981). %IRI was calculated (Cortés, 1997) to compare three size classes of fish (SL < 76 mm; 76 mm < SL < 90 mm; SL > 90 mm), chosen following an experimental balanced design also applied to NPMANOVA (see below).

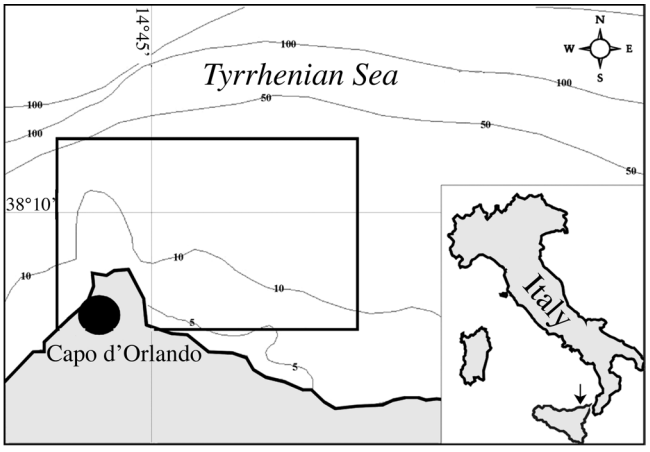

Figure 1. - Map of the study area (rectangle) with indication of main isobaths. *[Carte de la zone étudiée (rectangle) avec indication des isobathes principales.]*

Diet breadth was assessed using Levins' standardised index (Krebs, 1989):

$$B = \frac{1}{n-1}\left(\frac{1}{\sum p_j^2} - 1\right)$$

where B = Levins' standardised index ; p_j = proportion of diet that is made up of prey j ; and n = number of prey categories.

This index ranges from 0 to 1; a low value indicates a diet dominated by few prey items (specialist feeder), a high value indicates a generalist diet (Gibson and Ezzi, 1987; Krebs, 1989).

We analysed abundance data by means of a non-parametric multivariate analysis of variance (NPMANOVA) (Anderson, 2000, 2001; McArdle and Anderson, 2001) to detect differences in prey abundance between specimens caught in different years; after non-significant differences, data from different years were pooled for further analyses. We performed this analysis on 63 prey categories, belonging to 38 specimens caught in 1994 and 38 specimens caught in 1995; the specimens caught in 1996 were not considered due to the low number of full stomachs (only 5) examined in that period. Data were transformed to ln (x + 1); the analysis was based on Gower distances, with 999 permutations used. After non significant differences between years, NPMANOVA was performed on 77 categories, belonging to 31 specimens of three abovementioned size classes to detect differences in both prey abundance and prey weight among sizes; this analysis was repeated on 33 grouped prey categories.

In order to investigate individual diet variations we applied a multivariate analysis based on a principal component analysis performed on the proportions of the abundance of prey items (%PCA), specifically designed for diet composition data (De Crespin de Billy *et al*., 2000). In this %PCA, fish individuals (points on the graph) and their prey items (arrows on the graph) were analysed simultaneously and plotted on the same graph: the arrow length is proportional to the relative abundance of the prey while foraging behav-

iour can be deduced from the dispersion of individuals. There is specialisation towards a prey when points are concentrated at the end of an arrow. This analysis was performed on grouped prey categories according to positive results of the adequacy test of sample size.

RESULTS

A total of 134 juvenile red porgy ranging from 61 to 136 mm SL were examined. Ninety-four stomachs contained food ranging from 1 to 9 prey items (2.41 ± 0.19 s.e.). The adequacy test of sample size revealed sufficiency when prey were grouped in 33 categories; then satisfactory information on the diet of juvenile red porgy was drawn from these categories, although the minimum taxonomic level of prey was useful in identifying specific foraging areas. The analysis of prey items led to the identification of 78 taxa with crustaceans emerging as the dominant group according to all numeric indicators (Tab. I). Molluscs and teleosts were nearly equally represented in terms of IRI, the former accounting more in %N than in %W, vice versa for the latter. Polychaetes and echinoderms were represented by low values of all numeric indicators (Tab. I).

Among crustaceans, the best represented organisms in terms of IRI were hermit crabs (*Anapagurus* sp. and unidentified Paguridea), the ghost shrimp *Upogebia tipica* and the crab *Liocarcinus depurator*. Molluscs were mainly represented by gastropods, dominated in terms of IRI by *Philine aperta* and *Caecum trachea*, the latter showing very low %W values; bivalves and cephalopods were poorly represented in the diet. Unidentified teleosts and fish scales were the most frequent items, both represented by high IRI values (Tab. I). Among the prey items found, a few species were typical of different biocoenoses. They were the molluscs *Acanthocardia tuberculata, Acteon tornatilis* and *Neverita josephina*, the polychaetes *Psammolyce arenosa* and *Laetmonice hystrix*, the echinoderm *Astropecten aranciacus*.

Table I. - Prey items and dietary indexes in *Pagrus pagrus*. Only items with IRI >30 are included. (F = frequency of occurrence; %N = % in abundance; %W = % inweight; IRI = index of relative importance). *[Proies et indices alimentaires de* Pagrus pagrus. *Seules les proies avec un IRI >30 sont considérées. (F = fréquence d'occurrence ; %N = % en nombre ; %W = % en poids ; IRI = indice d'importance relative).]*

Prey items	%F	%N	%W	IRI	%IRI
Bivalvia	6.38	3.56	1.17	30.2	0.3
Gastropoda	45.74	34.12	7.37	1897.9	18.1
Caecum trachea	4.26	19.58	0.03	83.5	-
Philine aperta	12.77	4.45	5.54	127.6	-
Cephalopoda	3.19	0.89	4.42	17.0	0.2
Polychaeta	19.15	5.34	9.91	292.0	2.8
Crustacea	85.11	31.45	33.05	5490.1	52.2
Liocarcinus depurator	6.38	1.78	4.06	37.3	-
Upogebia tipica	6.38	2.97	11.93	95.1	-
Anapagurus sp.	12.77	4.45	4.43	113.3	-
Undetermined Paguridea	10.64	5.64	2.49	86.5	-
Echinodermata	14.89	4.45	4.50	133.3	1.3
Teleostei	51.06	14.83	33.51	2468.2	23.5
Unidentified Teleostei	21.28	6.82	19.83	567.2	-
Fish scales	26.60	7.12	11.43	493.5	-

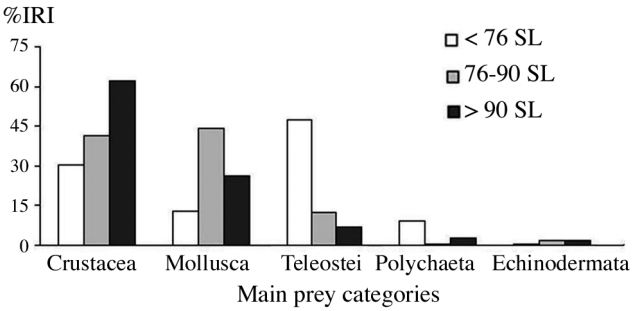

Figure 2. - %IRI for main prey categories in three size classes of juvenile *Pagrus pagrus*. *[%IRI pour les principales catégories de proies dans trois classes de taille de juvéniles de* Pagrus pagrus.*]*

When %IRI for main prey categories is considered over different predator size-classes, increasing importance for crustaceans and decreasing for teleosts with increasing fish size is noted, as shown in figure 2. The results of NPMANOVA showed no significant differences ($p > 0.05$) neither between 1994 and 1995 ($F_{1,74} = 0.714$) nor among size classes ($F_{2,90} = 1.315$ for prey abundance; $F_{2,90} = 0.796$ for prey biomass). Non-significant results were also obtained for grouped prey categories ($F^{2,90} = 1.474$ for prey abundance; $F_{2,90} = 0.232$ for prey biomass).

Levins' standardised index, calculated for the evaluation of diet breadth, was 0.20 for the numerical abundance and 0.15 for the biomass of prey items. As for %PCA performed on grouped prey categories (Fig. 3), the first two dimensions explained 45% of the variance. Teleosts and fish scales had the highest relative abundance among prey items. The majority of stomachs are concentrated in the centre of the graph in proximity of rare prey. A high number of stomachs is distributed towards hermit crabs, brachyuran crabs and prosobranch gastropods, indicating weak within-individual variation. An almost homogeneous distribution of stomachs across the plot reveals weak inter-individual variation.

DISCUSSION

Juveniles of *P. pagrus* in the southern Tyrrhenian Sea feed mainly on epibenthic invertebrates. The results of the dietary analysis indicate that the main food is decapod crustaceans, as also found by Labropoulou *et al.*

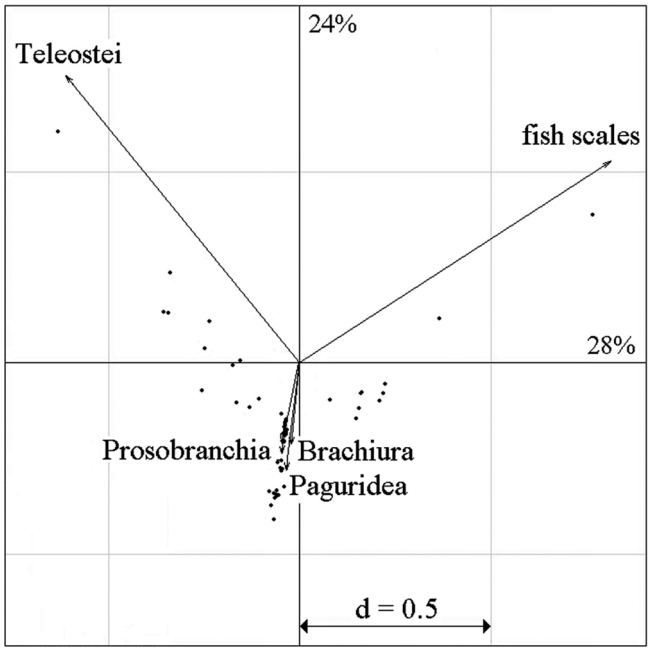

Figure 3. - First factorial plot of the %PCA performed on the proportions of the abundance of 33 grouped prey categories: only dominant items are indicated; points stand for individual stomach contents. *[Premier plan factoriel issue de l'ACP réalisée sur les proportions de l'abondance des proies regroupées en 33 catégories : seules les proies dominantes sont indiquées ; les points représentent les contenus stomacaux individuels.]*

(1999) on the Cretan shelf (eastern Mediterranean); molluscs and teleosts are also well represented, followed by less important prey like polychaetes and echinoderms. Nearly all prey items identified were benthic organisms. Some of them such as *Acanthocardia tuberculata*, *Acteon tornatilis* and *Neverita josephina* belong to the fine well-sorted sand assemblages (Pérès, 1982). Some other prey are typical of gravel (*Psammolyce arenosa* and *Astropecten aranciacus*) or coastal detritic bottoms (*Laetmonice hystrix*). The burrowing ghost shrimp *Upogebia tipica* is another important prey.

Such a diverse combination of organisms, belonging to various assemblages, suggests that juvenile red porgy explores different habitats during its feeding activity. In fact the continental shelf in the study area extends at least 1.7 miles offshore, and several different soft bottom biocoenoses succeed over such distance (Andaloro, 1994). Such array of biocoenoses allows the red porgy to exploit resources from various assemblages over a relatively small area, relying on slow-moving epibenthic prey like gastropods and hermit crabs. Despite the large number of taxa found in the stomachs analysed, few species accounted for most of the prey consumed, indicating specialist feeding as confirmed by the low Levin' index. The %PCA also provided evidence of individual feeding specialisation towards hard-bodied prey such as hermit crabs, brachyuran crabs and gastropods and revealed weak within-individual and inter-individual variation in the use of resources. Conversely, no specialisation towards teleosts and fish scales was evidenced by the %PCA, despite their high relative abundance.

In the range of sizes examined, belonging to young-of-the-year specimens (Porrello *et al*., 1998), prey do not seem partitioned among size-classes. Although no significant differences were found among size-classes, an increasing preference for crustaceans and decreasing for teleosts with fish size was noted. Such preference for prey category with fish size could be related to ontogenetic denture specialisation, as pointed out by Chakroun-Marzouk and Kartas (1987) in several *Pagrus* species. The increase in number and size of molar teeth on the lower jaw with fish size would allow larger individuals to better exploit armoured organisms, without scorning other prey like fishes, also eaten by adults (Manooch, 1977). The high frequency of occurrence of fish scales in the stomachs of red porgy from the southern Tyrrhenian, without other hard-to-digest parts like bones or otoliths, suggests a possible facultative lepidophagous behaviour, although further studies are needed to verify this.

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